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EFFECT OF COLD AND HEAT STRESS ON DIFFERENT STAGES OF WHEAT: A REVIEW

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At present food security mainly depends upon the increased production of main cereal such as wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Wheat is the main source of protein and calories for humans and ranked as third largest crop in the world after corn and rice. The world agriculture faces serious challenges to increased consumption, fulfill demand and allocation of land for other uses. Wheat productivity harshly effected by adverse environmental stresses. Climate change has marked influence the yield of wheat and further aggregate the situation by causing over wintering loss. Drought, salinity, high temperature and insufficient availability of nutrients are main environmental stresses which are responsible for low grain yield of wheat. Cold stress (low temperature) is a major environment factor that frequently effects the plant growth and crop productivity, by several aspects viz., photosynthesis, water transport, growth, cell division and ultimately crop yield. Cold stress also affects the wheat (*Triticum aestivum*) growth and productivity. High temperature stress (high temperature from critical threshold) cause irremediable damage to plant growth and development. It is suggested that to take imperative step to address these issue for increase the production of wheat. Here we review recent studies thermal (heat and cold) stress and their effects on different physiological and metabolic aspects, we also discussed the various quantitative and qualitative effects of cold and heat stress at germination, seedling as well as at reproductive stages that should provided valuable information to accelerate progress in breeding program for developing the thermal tolerant cultivars.
Key words: Climate change, environmental stresses, *Triticum aestivum*, abiotic stress

INTRODUCTION

The world agriculture faces serious challenges to increased consumption, fulfill calorie requirement and allocation of land for other uses (Curtis and Halford, 2014). Presantly, food security mainly depends on increased production of wheat (*Triticum aestivum* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.). Wheat is third largest crop in the world after corn and rice, and main source of protein and calories. About 82 to 85% of the total population depend upon wheat for fulfill their their protein and calories requirement (Chaves *et al.,* 2013). In addition, wheat is also used in variety of product such as flat and steamed breads, cakes, leavened bread, couscous and beer, biscuits and pasta (Curtis and Halford, 2014). Wheat has good nutrition value with 70% total carbohydrates, 59.2% starch, 12.1% protein, 6.7% pentosans, 2% reducing sugar, 1.8% lipids and provides 314 k cal/100 g of food. Wheat is also a good source of vitamins and minerals, and contains 37 mg/100 g calcium, 5.4 mg/100 mg nicotinic acid, 4.1 mg/100 g iron, 0.45 mg/100 g thiamine and 0.13 mg/ 100 g riboflavin (Lorenz, 1991). Due to high level of adaptation wheat is also used as fuel. Wheat is cultivated under both irrigated as well rain-fed condition in tropical and subtropical region. On the other hand, wheat production harshly affected by adverse environmental stresses (Rahaie *et al*., 2013). Drought, salinity, high temperature and insufficient availability of nutrients are main environmental stresses which are responsible for low grain yield of wheat (Subedi *et al.,* 2000). A stress (deficiency and/or access of any factor) affects almost all the aspect of plant metabolism, growth and development. Plant response to stress depends upon different factors such as time, duration, degree of stress, and growth stage of plant (Gupta and sheoran, 1983). Due to active mode of life, plants adopted many strategies against different stress like salinity, thermal stress, which adverslly affect the plant growth and productivity (Gill *et al.,* 2013).

Cold stress (low temperature) is a major environment factor that frequently effects the plant growth and crop productivity, by several aspects viz., photosynthesis, water transport, growth, cell division and ultimately crop yield. Cold temperature (0-15°C) is one of the most limiting factors for growth and productivity of wheat and significantly effects the early growth of winter wheat (Ruelland *et al.,* 2009) and freezing stress (<0°C) result in ice formation with in plant tissue (Sanghera *et al.*, 2011). Cold stress inhibit the activity of Calvin Benson cycle and create an imbalance between light

absorption and light use, also caused the oxidative stress (Hu *et al.,* 2008).

High temperature stress (temperature above threshold) cause irremediable damage to plant growth and development. In this menuscript we have reviewed the effects of heat and cold stress on different stages of wheat and provided a guide line for future research to minimize the thermal effects and produce new cultivars which perform well under tempertaure stress conditions.

Cold Stress Effect:

***Germination stage*:** Yoshida (1981) discussed that chilling injury is a serial problem during early seedling and germination stage in sessile plants. Buriro *et al*. (2011) find out that wheat germination percentage was 80-97% at 10-30°C and optimum temperature for wheat seed germination is 20-30°C. Germination is drastically less below 8-10°C (Zabihi *et al.,* 2011). Germination stage of wheat is very sensitive to soil temperature because during this stage seed needs water for breathing and enzymatic activity (Voorhees *et al.*, 1981). Seed vigor and germination are fundamental for the achievement of stand establishment of crop; cold stress and low moisture are the limiting factors during the germination stage (Brigg *et al.*, 1979). The rate and amount of uptake of nutrients and water decreased under cold stress, results in cell desiccation. Freezing stress (extreme form) cause ice formation in cell liquid, leads to dehydration and death of plant (Scott *et al*., 2004; Wan *et al*., 2009).

***Growth stages and morphology*:** Nehar *et al*. (2012) found that chilling injury in plants reduced the seedling growth, white specks and bands, leaf whiting, seed discoloration and reduce the rate of tillering. Solanke and Sharma (2008) discussed that seedling stage of plant is much sensitive to low temperature and many phenotypic symptoms are present like chlorosis, necrosis, tissue break down, leaf expansion reduce, surface lesions and wilting. Plant cellular structure and components are damaged by cold stress, ontogeny of organelles and process of development may also be disrupted by low temperature stress (Kratsch and Wise, 2000). Yellowing of leaves, stunted plant, bushy plant and early maturity are the morphological symptoms induced by cold stress (Nahar *et al.*, 2009).

***Photosynthesis and reproductive phase*:** Reproductive phase of plant is more susceptible to cold stress. Low temperature causes the disruption of meiosis, stunted development of pollen grain, pollen sterility and pollen tube formation during the formation of male gametophyte and, it effect the disruption of meiosis, callose deposition in style, reduce stigma receptivity and arrest the fertilizer process during the female gametophyte formation. At flowering stage, cold stress may result in delayed flowering, distorted flower and reduce the kernel filling rate and then small, unfilled and aborted seed produced (Thakur *et al.,* 2010). Photosynthesis is the key organ which disturb by cold stress. Cold stress limits the photophosphorylation, reduces the activity of stomatal and carbon assimilation enzymes like ATP synthase and RuBisCO regeneration (Allen and Ort, 2001). Freezing temperature also causes osmotic stress, escort the cellular dehydration and reduce the nutrients and water uptake by roots (Chinnusamy *et al.*, 2007).

***Wheat yield*:** In spring wheat, at the stage when stamen and pistil differentiate into anther, low temperature can cause the sterility and significantly reduce the yield (Paulsen and Heyne, 1983). Thakur *et al.* (2010) discussed that low temperature decrease the seed setting, breakdown of fertilization, poor seed filling and finally reduces the grain yield. Dildar and Rasul, (2009) reported that decrease in minimum temperature, reduce the grain yield of wheat (Fig. 1).

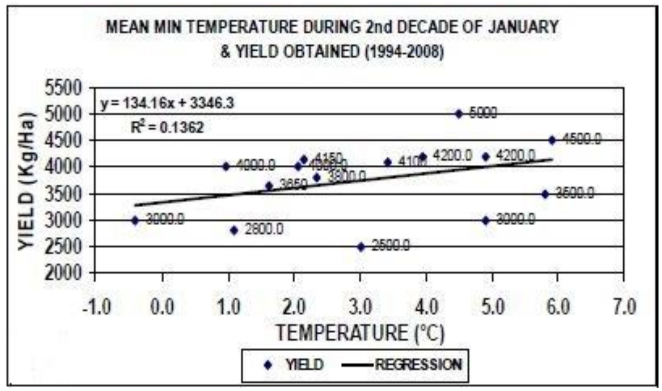

Figure 1. Mean minimum temperature and yield of wheat during second decade of January (1994-2008).

High Temperature:

***Germination and tillering stage*:** Temperature is a main factor for abiotic stress and responsible for agriculture yield and productivity. To obtain the better crop stand and higher yield, seed germination and seed vigor are the most important traits and seed germination mostly depends on temperature and range of temperature for good germination depend upon the crop species. Khodabandeh *et al.* (2003) discussed that ptimum tempertaure for germination process is 4°C, but tempertaure above this range not suitable for optimum germination percentage. Abbasal-Ani and Hay (1983) described that seedlings root system of barley, wheat, oats and rye is faster at 15 to 20°C (high temperature) and shorter at 5°C (low temperature). Prasad *et al*. (2006) studied that when temperature increased above the base temperature (Tb) under constant soil moisture, then seed germination percentage tends to increase and it reached at maximum value. Germination percentage also increased when temperature increases from base to optimum range and this percentage decreases above optimum temperature. During the early stage of germination, high temperature (45°C) caused cell death and damaged the embryo in *Triticum aestivum*. High temperature is not suitable for wheat growth and new seedlings

establishment (Essemine *et al.*, 2010). Johkan *et al.* (2011) observed the relation between number of tillers and high temperature and reported that number of tillers decreased under high temperature, especially high night temperature.

***Grain filling stage*:** Wheat is mostly grown during winter, therefore, sensitive to high temperature, and during mid anthesis stages, extreme temperature affect fertilization and seed set which ultimately reduce the wheat yield (Ferris *et al.*, 1998). Heat stress also reduces seed size and decreases seed filling duration. During grain filling stage, heat stress resulted in ultra-structure change in aleurone layer, shrinkage in grains with reduced weight, affect gluten strength and diminishing the wheat flour quality (Dias *et al.*, 2008). High temperature also alters the anatomy of plants, reduces cell size, increase stomatal density and closures the stomata (Wahid, 2013).

***Flowering and panicle development*:** Climate change have drastic impact on wheat crop and high temperature possesses the negative effect on wheat, thus reduce the productivity and yield. At floral initiation and spikelet development stage, high temperature decrease the number of grains and adversely reduces the maximum yield potential (Yang *et al.,* 1996; Janjua *et al.*, 2010). Sensitivity of pigmentation in wheat and maize is also affected by heat stress and heat stress also effect on PS II (Photosystem II) which results in low seedling growth and leaf development (Tewari and Tripathy, 1988). Wardlaw *et al*. (2002) described that yield and production of inferior quality of cereals is affected by high temperature and similarly Wahid *et al*. (2007) reported that heat stress also has effect on vegetative and reproductive stages. During flowering stage; cereals, groundnut and dry bean, loose seed set and show pollen sterility under heat stress conditions (Prasad *et al.,* 2000). Heat stress with drought, have the more effects on growth and productivity of crops, and in combination alter the physiological process like photosynthesis, transcript expression and accumulation of lipids (Savin and Nicolas, 1996; Jiang and Huang, 2001).

***Photosynthesis, respiration and development stages*:** Leaf appearance and elongation is highly dependent on high temperature and decreases the leaf elongation duration (Prasad *et al.*, 2006). Batts *et al.* (1998) observed that during the reproductive stage, heat stress retard the root growth because of decreased carbon partitioning to roots. High temperature above 40°C affects the photosynthesis rate adversely and decreases the solubility of O_2 and CO_2. Thus reduce the rate of photosynthesis and increase respiration rate, and increase level of CO_2 than O_2 (Lea and Leegood, 1999). Rubisco activity decreases at high temperature (Prasad *et al.,* 2004). Byrla *et al*. (2001) told that mitochondrial respiration is highly dependent on temperature. The rate of respiration is the highest at 40 to 50°C but decreases when temperature is above 50°C, destruction of respiratory mechanism. Root and leaf respiration also decrease under short term drought conditions. Seed respiratory losses increases under heat stress condition because of influx of assimilates, ultimately reduces the yield (Wardlaw *et al.,* 1980). Rehman *et al*. (2009) reported that heat stress affects the wheat productivity in arid, semi-arid, tropical and sun subtropical region. Castro *et al*. (2007) told that heat stress has negative effect on wheat growth and development, change the morphology of wheat, reduce plant height, grain weight, kernel weight, kernel number and grain growth duration. Din *et al.* (2010) found the effects of temperature on development and grain formation in ten genotypes of spring wheat. High (0.538) heat stress intensity is responsible for 53.75% reduction in grain yield and 15.38% reduction in tiller under late planting conditions. Shah and Paulsen (2005) evaluated that at maturity, high temperature reduced the water use efficiency (WUE), decreased the viable leaf area, photosynthesis rate, kernel weight, grain and shoot mass and sugar content. Schuster *et al.* (1990) recorded that when temperature exceed its normal range (15 to 45°C), it decreases the enzymatic activity, which is responsible for photosynthesis.

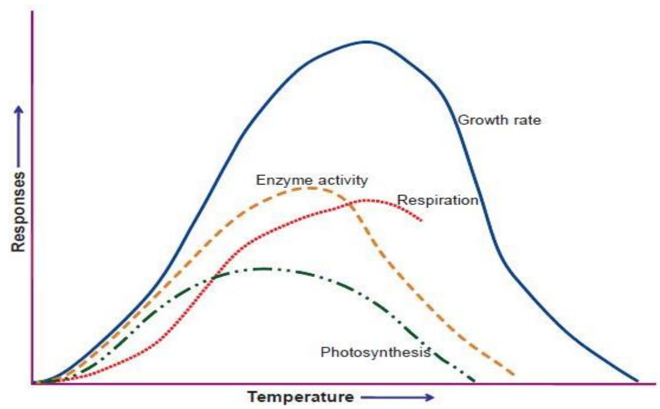

Figure 2. Schematic diagram of the effect of temperature on respiration, photosynthesis, enzymatic activity and growth rate of plants (Fitter and hay, 2002).

***Final yield*:** High temperature affects the both source and sink for assimilates and reduces crop yield (Mendham and Salsbury, 1995). Leaf area and photosynthesis, shoot, grain biomass hastily decreased under high temperature (Shah and Paulsen, 2003). Wheat is most sensitive to high temperature than other crops. When temperature exceed from normal (27°C) to high night temperature (32°C), it results 90% less grain formation (Mohammad and Tarpley, 2010). Wheat plant reduces 20% grain weight when is grown under high night temperature as compared to normal temperature. Due to dark respiration, *T. aestivum* decreases its yield, produces immature grains and when temperature increase (24°C/14°C) to (31°C/18°C), reduces yield up to 39%, dry weight 20%, harvest index 24% and 50% reduction in number of grain spike (Prasad *et al.*, 2011).

Table 1. Reduction in yield and yield component of wheat (T. aestivum), due to high temperature (Rahman *et al*., 2009; Prasad *et al*., 2011).

Plant species	Temperature and duration	Reduction %
Triticum aestivum	5°C greater than optimum level, from sowing to 60 days after sowing, 61-81 days after sowing and 81 days after sowing.	Grain yield per plant: 46% Grain weight: 19% Grain per spike: 18%
Triticum aestivum	18°C / 31°C (night/day); heading to harvest maturity	Grain per spike: 50% Grain yield per plant: 39%

***Management of stresses*:**

1. Kang and Saltveit (2002) reported that 0.5 mM salicylic acid improved the cold stress affects in maize, rice and cucumber. We need to check this quantity on wheat plant.
2. Exogenous application of salicylic acid decreased the freezing injury in winter wheat leaves which is grown under low temperature condition (Tasgin *et al.*, 2003).
3. Iqbal *et al.* (2016) applied exogenous growth enhancer for improvement in germination and post germination to manage heat stress.
4. Now a day a number of genes have been identified but knowledge of transcriptional control of cold and heat stress response is limited.
5. For the improvement of wheat yield under changing climatic conditions, researcher's mostly focus on developing the thermo tolerant varieties, need step toward tissue culture technique and need research on phenotypic flexibility.
6. Symbiotic association of root with arbuscular fungi improves the plant resistance against stresses (Koide and Schreiner, 1992). This needs research on symbiotic association against low and high temperature stress.
7. Photo-inhibition of photosynthesis is a major issue in plants under low or high temperature conditions. Critical study is needed to avoidance of photo-inhibition in crops.

***Conclusion*:** Wheat is a very important crop throughout the world and good source of calories and proteins for humans. The low or high temperature causes stress in wheat and predicted to boost stress under the changing climate. Heat stress extensively affects the grain setting and ultimately reduces the grain yield. Duration, timing and intensity of heat stress decide its impact on wheat yield. The effect of heat stress can be minimized by agronomic strategies, developing heat tolerant genotype and applying the growth enhancers.

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